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CLAIMS

What is claimed is:

1. A fuel cell system comprising:
 - a fuel cell stack, said fuel cell stack including a plurality of fuel cells each including an anode and a cathode, said fuel cell stack receiving a hydrogen anode gas and a charge cathode gas and exhausting an anode exhaust gas and a cathode exhaust gas;
 - a compressor, said compressor compressing the charge gas to provide the charge cathode gas;
 - a first coolant loop including a cooling fluid flowing therethrough, said first coolant loop including a first heat exchanger receiving and cooling the compressed charge gas and a second heat exchanger for cooling the cooling fluid that has been heated by the compressed charge gas and the fuel cell stack;
 - and
 - a first recuperative heat exchanger also receiving the compressed charge gas and providing additional cooling for the compressed charge gas.
2. The system according to claim 1 wherein the recuperative heat exchanger also receives the cathode exhaust gas to cool the charge air flowing therethrough.
3. The system according to claim 2 further comprising a cathode exhaust gas expander, said cathode exhaust gas expander being mechanically coupled to the compressor by an expander shaft, said cathode exhaust gas expander receiving the heated cathode exhaust gas from the recuperative heat exchanger so as to cause the expander shaft to rotate to drive the compressor.
4. The system according to claim 3 further comprising an anode exhaust gas combustor, said anode exhaust gas combustor receiving the anode exhaust gas and the cathode exhaust gas, said anode exhaust gas combustor

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burning residual hydrogen in the anode exhaust gas to further heat the cathode exhaust gas before it is sent to the cathode exhaust gas expander.

5. The system according to claim 3 further comprising a second recuperative heat exchanger and an expander heat charger, said second recuperative heat exchanger and said expander heat exchanger being part of a second coolant loop having a cooling fluid flowing therethrough, said second recuperative heat exchanger also receiving and cooling the compressed charge gas before it is applied to the fuel cell stack, said expander heat exchanger receiving the cooling fluid in the second coolant loop flowing through the second recuperative heat exchanger and cooling the cooling fluid.

6. The system according to claim 1 wherein the second heat exchanger is a radiator fan module that cools the cooling fluid in the first coolant loop by forced air.

7. The system according to claim 1 further comprising a humidification unit that receives the compressed charge gas, said humidification unit mixing water vapor with the compressed charge gas before it is sent to the fuel cell stack.

8. The system according to claim 1 further comprising a liquid separator, said liquid separator receiving the cathode exhaust gas and removing liquid water therefrom.

9. The system according to claim 1 further comprising an exhaust gas heat exchanger that receives and cools the cathode exhaust gas.

10. The system according to claim 1 wherein the fuel cell system is on a vehicle.

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11. A fuel cell system comprising:

a fuel cell stack, said fuel cell stack including a plurality of fuel cells each including an anode and a cathode, said fuel cell stack receiving a hydrogen anode gas and a charge cathode gas and exhausting an anode exhaust gas and a cathode exhaust gas;

a compressor, said compressor compressing the charge gas to provide the charge cathode gas; and

a cathode exhaust gas expander, said cathode exhaust gas expander being mechanically coupled to the compressor by an expander shaft, said cathode gas exhaust expander receiving the cathode exhaust gas and causing the expander shaft to rotate to drive the compressor.

12. The system according to claim 11 further comprising an anode exhaust gas combustor, said anode exhaust gas combustor receiving the anode exhaust gas and the cathode exhaust gas, said anode exhaust gas combustor burning residual hydrogen in the anode exhaust gas to heat the cathode exhaust gas before it is sent to the cathode exhaust gas expander.

13. The system according to claim 11 further comprising a recuperative heat exchanger and an expander heat charger, said recuperative heat exchanger and said expander heat exchanger being part of a coolant loop having a cooling fluid flowing therethrough, said recuperative heat exchanger receiving and cooling the compressed charge gas before it is applied to the fuel cell stack, said expander heat exchanger receiving the cooling fluid flowing through the recuperative heat exchanger and cooling the cooling fluid.

14. The system according to claim 11 further comprising a liquid separator, said liquid separator receiving the cathode exhaust gas and removing liquid water therefrom.

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15. The system according to claim 11 further comprising a heat exchanger that receives and cools the cathode exhaust gas.

16. The system according to claim 11 wherein the fuel cell system is on a vehicle.

17. A fuel cell system for a vehicle, said system comprising:

- a fuel cell stack, said fuel cell stack including a plurality of fuel cells each including an anode and a cathode, said fuel cell stack receiving a hydrogen anode gas and a charge air cathode gas and exhausting an anode exhaust gas and a cathode exhaust gas;
- a compressor, said compressor compressing the charge air to provide the charge air cathode gas;
- a first coolant loop including a cooling fluid flowing therethrough, said coolant loop including a first heat exchanger receiving and cooling the compressed charge air and a second heat exchanger for cooling the cooling fluid that has been heated by the compressed charge air and the fuel cell stack;
- a first recuperative heat exchanger also receiving the compressed charge air and providing additional cooling for the compressed charge air, said first recuperative heat exchanger receiving the cathode exhaust gas to cool the charge air;
- an anode exhaust gas combustor, said anode exhaust gas combustor receiving the anode exhaust gas and the cathode exhaust gas combustor, said anode exhaust combustor burning residual hydrogen in the anode exhaust gas to further heat the cathode exhaust gas; and
- a cathode exhaust gas expander, said cathode exhaust gas expander being mechanically coupled to the compressor by an expander shaft, said cathode exhaust gas expander receiving the heated cathode exhaust gas

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from the anode exhaust gas combustor so as to cause the expander shaft to rotate to drive the compressor.

18. The system according to claim 17 further comprising a second recuperative heat exchanger and an expander heat charger, said second recuperative heat exchanger and said expander heat exchanger being part of a second coolant loop having a cooling fluid flowing therethrough, said second recuperative heat exchanger also receiving and cooling the compressed charge gas before it is applied to the fuel cell stack, said expander heat exchanger receiving the cooling fluid in the second coolant loop flowing through the second recuperative heat exchanger and cooling the cooling fluid.

19. The system according to claim 17 wherein the second heat exchanger is a radiator fan module that cools the cooling fluid in the first coolant loop by forced air.

20. The system according to claim 17 further comprising a humidification unit that receives the compressed charge air, said humidification unit mixing water vapor with the compressed charge air before it is sent to the fuel stack.

21. The system according to claim 17 further comprising a liquid separator, said liquid separator receiving the cathode exhaust gas and removing liquid water therefrom.

22. The system according to claim 17 further comprising a separator heat exchanger that receives and cools the cathode exhaust gas.

23. A fuel cell system comprising:

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a fuel cell stack, said fuel cell stack including a plurality of fuel cells each including an anode and a cathode, said fuel cell stack receiving a hydrogen anode gas and a charge cathode gas and exhausting an anode exhaust gas and a cathode exhaust gas; and

an anode exhaust gas combustor, said anode exhaust gas combustor receiving the anode exhaust gas, said anode exhaust gas combustor burning residual hydrogen in the anode exhaust gas.

24. The system according to claim 23 wherein the anode exhaust gas combustor also receives the cathode exhaust gas so that the anode exhaust gas combustor heats the cathode exhaust gas by burning the residual hydrogen in the anode exhaust gas.

25. The system according to claim 23 wherein the fuel cell system is on a vehicle.

26. A fuel cell system comprising:
a fuel cell stack, said fuel cell stack including a plurality of fuel cells each including an anode and a cathode, said fuel cell stack receiving a hydrogen anode gas and a charge cathode gas and exhausting an anode exhaust gas and a cathode exhaust gas; and
a heat exchanger, said heat exchanger receiving and cooling the cathode exhaust gas.

27. The system according to claim 26 wherein the fuel cell system is on a vehicle.